S282 Astronomy

The age of the Jewel Box

The Open University

Study time: 2 hours

Summary

In this activity you will determine the approximate age of the Jewel Box star cluster by plotting a Hertzsprung–Russell (H–R) diagram. You will plot the positions of stars in the cluster by using a colour image to estimate their spectral class (from their colour) and relative brightness (from the image size of the stars).

You should be familiar with the H–R diagram (Section 4.2 of *An Introduction to the Sun and Stars*) and the properties of clusters of stars (Section 3.2.4 and 4.2.5) before attempting this activity.

Learning outcomes

- Be able to plot the stars of a cluster on an H–R diagram and estimate the age of the cluster.
- Appreciate the difficulties of working with real data.

Preparation

You will need:

- The printed colour plate showing the Jewel Box cluster and the colour/brightness gauge (supplied within your course mailing).
- The blank H–R diagram worksheet (which also provides sample cluster H–R diagrams in the same form). This worksheet is supplied at the back of this activity.
- Scissors, ruler and a pencil.
- A hand lens, a clear (not frosted) plastic A4 pocket and a washable marker might be useful.

This activity is best done in reasonably bright light, daylight if possible.

Note: if you have poor colour vision you may find you are unable to do this activity without help.

Background to the activity

The Jewel Box is an open cluster in the constellation Crux, the Southern Cross. It looks like a star to the unaided eye, but is only visible from the southern hemisphere. The cluster contains just over 100 stars, spans about 6 pc and lies about 2300 pc away. It was named the Jewel Box from its appearance in the telescope, which was described by Sir John Herschel as ‘a casket of variously coloured precious stones’.

In this image, as in most images of stars, the photographic process means that the brighter the star the bigger it appears.

In this activity you will be drawing a simple H–R diagram of the Jewel Box cluster in the form of a colour–magnitude diagram (see page 133 of *An Introduction to the Sun and Stars*). These are usually constructed from observations using images in two filters (blue, B, and visual, V) from which the V magnitude (which is related to luminosity *if* all the stars are at the same distance) and colour (in the form of colour index $B - V$ which is indicative of temperature) are derived. You will use the size of the stellar images as a measure of brightness (V) and the perceived colour of the star as a measure of the colour index ($B - V$).

Question 1

From your study of Section 4.2 of *An Introduction to the Sun and Stars*, explain why it is possible to estimate the age of a star cluster by plotting its stars on an H–R diagram.

The activity

- Carefully cut the strip containing the colour/brightness gauge away from the Jewel Box image. If you put the image into a plastic pocket then it is easy to mark what you have done without messing up the image, but you may find the pocket makes the colours difficult to see.

Examine the image when you have done this.

- Do all the stars appear to be the same colour?

- ❑ The less bright, smaller stars nearly all show distinct colouring. The brighter ones tend to appear white in the centre, but most of them have a rim of colour around the limb. The white centres are due to overexposure of the photographic plate. (This is the same factor that makes the brighter stars appear so much larger than the dimmer ones. They are not really noticeably bigger at this distance, and certainly not as big as they appear in images like this.)

Question 2

Can you tell where the edge of the cluster lies?

- Using pencil if you are working directly on the image, or marker if using the plastic pocket, outline where you think the boundaries of the cluster are.
- Place an X where you estimate the centre of the cluster of stars to be and use a ruler to draw a 4 cm square about this centre point. Measure the brightness of the star closest to the upper left-hand corner of your square from its size in the image in comparison to the dots on the colour/brightness gauge. Estimate the star's colour using the colour portion of the colour/brightness gauge and mark a dot on the blank H–R diagram in the box that corresponds to the brightness and colour you have measured for your first star.
- Mark the star you have just measured and then proceed in some systematic fashion to measure the brightness and colour of every star within your 4 cm square. (Remember that the colours of the brighter stars are only apparent around their edges where the image is not overexposed.)

Question 3

Do the Jewel Box stars on your diagram appear to be randomly scattered or do they fall in any kind of pattern? What problems have you encountered in measuring the colour and brightness of the individual stars?

Stars in front of or behind the Jewel Box that are not part of the cluster also appear in the image. These are known as 'field stars'. If time allows, estimate how many of these stars are included in your measurements by drawing a 4 cm square near the edge of the print and measure the colour and brightness of the stars within this square. Mark these stars on your H–R diagram using another symbol, e.g. × instead of a dot.

Question 4

Do the field stars appear to fall randomly on your diagram or do they appear to fall in any kind of pattern?

Question 5

Compare your answers to Questions 3 and 4. Why do you think the similarities or differences between the two star patterns exist?

Question 6

Using the sample H–R diagrams on the worksheet give a rough estimate of the age of the Jewel Box cluster.

Question 7

Thinking about the relationship between mass, luminosity and colour of main sequence stars, review what the three sample H–R diagrams show about the relative main sequence lifetimes of O/B stars compared to A/F/G stars compared to K/M stars.

Answers to questions

Question 1

A cluster occurs because the stars in it form from the same dense cloud at the same time. This means that the stars in the cluster are the same age and have similar composition, so they vary only in mass. Because stars of different masses evolve at different rates, and we can tell the mass of a main sequence star from its position on the main sequence, this means we can estimate the age of the cluster from the masses of the stars remaining on the main sequence compared to those that have left it.

Question 2

The edge of the cluster is not very clearly defined, but you should have identified a denser area of stars about 8–10 cm across, with the bright orange star a little off centre.

Question 3

You may have been surprised by just how many stars there were in a 4 cm square! Most of the stars should fall in a band stretching up to the left from the bottom right-hand corner of the H–R diagram, from brightness 10, colour K2 or M to about brightness 5 or 6, colour A – this corresponds to the main sequence. There are a few hotter brighter stars in the top left-hand corner, and you may have found some in other areas, including the bright orange star near the centre of the cluster. You may have had problems deciding which colour or brightness category some of the stars fall into, and in particular seeing the colours on some of the less bright stars, and may have rather a lot plotted as spectral class A – the class which appears as white.

Remember that on the H–R diagram the temperature increases to the left, corresponding to shorter wavelengths on the peak of the stars' black-body spectrum, so that hot stars appear blue, with the colour fading through white to yellow then orange and reddish for low temperature stars, corresponding to the spectral classes on the colour/brightness gauge.

Question 4

Generally the field stars will appear to be more randomly spread across the lower half of the diagram.

Question 5

The field stars are at different distances from us than the Jewel Box cluster. Using an image taken from Earth we are looking at apparent brightness, not absolute brightness, so a more distant star will appear less bright than a similar star in the Jewel Box, and will plot lower on the diagram. But bear in mind that there will also be field stars in the same region of the sky as the cluster, and there may be one or two outlying members of the cluster in the region you chose for your field stars.

Question 6

With the exception of the bright orange star almost all the rest plot on the main sequence. There appear to be none plotting on the red giant branch as in the middle aged and old clusters on the worksheet and M67 in Figure 4.10b of *An Introduction to the Sun and Stars*. The cluster therefore is similar to the young cluster in Figure 4.10a, so we can conclude that it is less than 100 million years old.

In fact the Jewel Box is only about 12 million years old. The bright orange star is known as κ (kappa) Crucis. It is a very large (hence very luminous) star which, though quite young in stellar terms, has already moved into a red supergiant phase.

Question 7

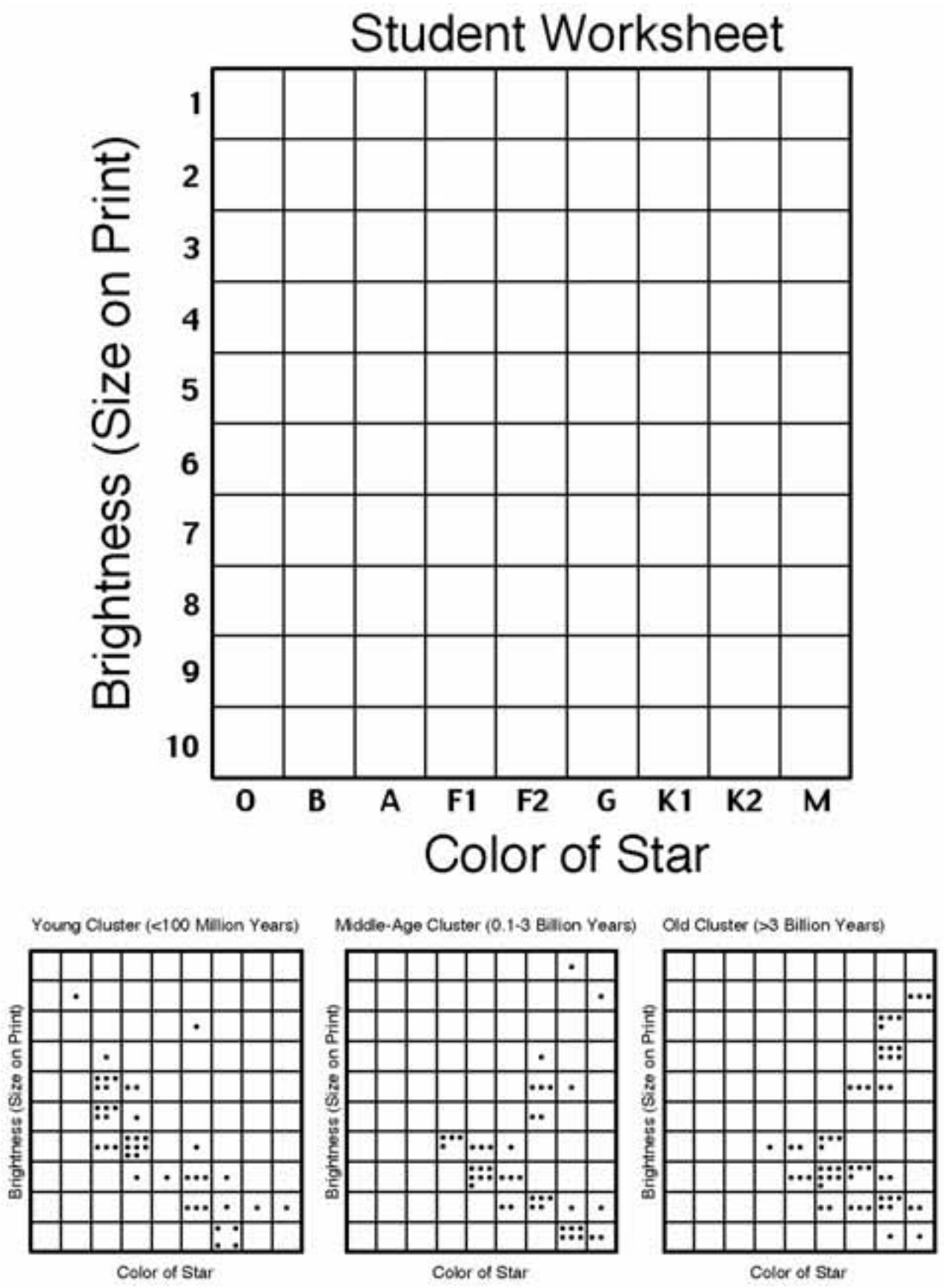
The more massive a star the hotter and brighter it is, and so it plots higher up the main sequence. More massive stars also burn the hydrogen in their cores faster, and so have shorter main sequence lifetimes. Very massive stars spend only of the order of 10 million years on the main sequence and then become supergiants with luminosity more than 10^4 times that of the Sun. As lower mass stars leave the main sequence they become red giants, which are cooler but more luminous than main sequence stars, and plot in a distinct region above and to the right of the main sequence on the H–R diagram.

As a cluster ages the stars in it reach the end of their main sequence lives, so if you plot the cluster stars on an H–R diagram as you have here you can see which are the hottest and brightest stars which remain on the main sequence – the turn-off point – and hence estimate the age of the cluster. The sample H–R diagrams show that the massive O/B stars are very short-lived since they have moved away from the main sequence even in the first 100 million years. By 3 billion years many A/F/G stars have completed their main sequence lives, but the low mass K/M stars still remain on the main sequence.

Acknowledgements

Worksheet: National Optical Astronomy Observatory

Colour plate: Nick Suntzeff (CTIO)/NOAO/AURA/NSF



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